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BUILDING RESEARCH TRANSLATION

An Investigation of the Protection of Dwellings From External Noise Through Facade Walls

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UNITED STATES DEPARTMENT OF COMMERCE
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An Investigation of the Protection of Dwellings From External Noise Through Facade Walls

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FORE

The United States/French Cooperative Program on Building Technology entails an exchange of personnel between the National Bureau of Standards (Building Research Division) and the Centre Scientifique et Technique du Bâtiment (CSTB) of France. The program also involves the exchange of information between the two research organizations.

It is felt that some of the documented information can be usefully shared with the U.S. building industry; and, therefore, certain papers were selected for reproduction in media on sale to the public by the Government Printing Office. It should be understood that the CSTB documents made public through such media as this TECHNICAL NOTE do not necessarily represent the views of the National Bureau of Standards on either policy or technical levels.

At the same time, building researchers at the National Bureau of Standards consider it a public service to share with the U.S. building industry certain insights into French building technology.

James R. Wright

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AN INVESTIGATION OF THE PROTECTION OF DWELLINGS FROM EXTERNAL NOISE THROUGH FAÇADE WALLS

by

P. Gilbert

This paper is translated from the French original and is published under the Building Research Division/ Centre Scientifique et Technique du Bâtiment information exchange program.

An investigation was conducted to determine to what extent the installation of balconies and loggias at various angles of elevation from a noise source could improve the sound insulation of a façade wall. Measurements of the sound pressure level were first carried out on two types of façade, one incorporating traditional window joinery and the other incorporating sealed glazing. Following this, the sound insulation provided by façades fitted with open and closed balconies and loggias (with and without sound absorbent materials applied) was determined and compared with the previous measurements. It was found that for angles of elevation greater than 30°, both the closed balcony and the loggia fitted with absorbent materials appreciably improve the sound insulation, whereas the open balcony does not.

Key words: Façade; noise; sound insulation; sound pressure level; walls.

1. Purpose of the Investigation

In the last few years dwellings have been subjected to endlessly increasing amounts of external noise due to road traffic, aircraft, etc.

It is extremely difficult to achieve sufficient attenuation of intense noises by the façade wall of a block of flats in order to ensure that the internal environment within the building shall be acceptable. There are two reasons for this:

1. Lightness and rigidity of window glazing limits sound insulation of the façade to a relatively low value.

2. Windows are frequently left open during a large part of the year, thus reducing the sound insulation of the façade to zero.

The investigation reported in this paper was undertaken in order to determine to what extent such items as balconies and loggias could improve the sound insulation of a façade.

When the external noise level is known, a knowledge of the insulation value of the façade enables the internal noise level to be determined and its compatibility with the requirements of the occupants to be assessed.[1/] In general, it will be found that an acceptable noise level at a noisy location can only be achieved with closed windows. This gives rise to a thermal comfort problem.[2/] However, one can also determine the acoustic environment in which it is permissible to build with ordinary façades.

This investigation has been made possible by the financial support of the "Délégation générale à la Recherche scientifique et technique" as part of the concerted activity of Plan IV within the field of building and civil engineering.

2. Arrangement for Measuring the Sound Insulation of a Façade

An end wall of the new C.S.T.B. acoustic laboratory has been specially fitted out for making the measurements.

The two rooms on the upper story, the openings of which can be seen in the photograph in figure 1, are the measuring rooms.

The openings can be fitted with various types of windows and glazed doors. Bolts are fitted enabling balconies and loggias to be attached to the façade.

The area in front of the building is asphalted and marked out with coordinates. A mobile tower carrying the noise sources can be moved about over this area.

1/ Cahiers 762; Volume No. 88; C.S.T.B.; October 1967 and Cahiers 871, Volume No. 100; June 1969

2/ Cahiers 608; Volume No. 72; C.S.T.B.; February 1965

3. Method of Measurement

The measurements were carried out on two types of façade, one incorporating traditional window joinery, the other incorporating sealed glazing. The purpose of these measurements was to investigate the effect of:

1. The angle of incidence of sound waves, characterized by the angles of elevation (ϕ) and azimuth (γ) defining the direction of arrival of the sound waves at the center of the façade (figure 2). The angles ϕ and γ were given the values 0, 30, 60 and 80 degrees. In the case where the noise-source is higher than the center-point of the façade was not examined.

2. The presence of balconies and loggias, with and without absorbent material.

Some data were also obtained on the effect of glass thickness and the air-tightness of windows on the sound insulation obtained. For a given incidence (ϕ, γ) of sound waves arriving freely at the façade, the normalized sound insulation has, for the purposes of this investigation, been taken as:

$$D_n = L_I - L_{pr} + 10 \log(T/0.5) \quad \text{dB}$$

where:

L_I is the sound intensity level of the waves incident on the façade.

L_{pr} is the reverberant sound pressure level within the room behind the façade.

T is the reverberation time measured in this room.

The method of measurement follows directly from this definition.

A loudspeaker directed towards the center of the façade (figure 3) is placed at a distance d from this point, this distance being considerably greater than the dimensions of the façade wall. At this distance, the loudspeaker produces a sound level, the value of which is known from a preliminary free-field calibration.

The reverberant sound pressure level in the test room is measured while the loudspeaker is operating at incidence (ϕ, γ) and at a distance d from the center of the façade. This interior measurement is made using a microphone that is in continuous motion inside the room (figure 4), being mounted on an arm which rotates about an inclined axis. This arrangement enables the quadratic mean sound pressure to be determined.

The values L_I, L_{pr}, and T are measured and the value of the normalized sound insulation, D_n, is deduced from them.

Precautions had to be taken to minimize the reflection from the ground since this caused sound waves to arrive at the wall with a different incidence, and these reflected waves could interfere with the direct waves. It was mainly due to the directional properties of the loudspeakers used that we were able to reduce the amplitude of the reflected waves sufficiently.

4. Description of the Types of Façade Used in This Investigation

The façades studied were those of two second-floor test-rooms (figure 1). They were 3.30 m wide by 2.50 m high. The total area of each façade occupied by windows and doors was almost exactly $3.6 m^2$, or 44% of the total area of the façade. The test room dimensions were 3.30 x 2.50 x 4.25 m, giving a volume of $34 m^3$. The façade wall had an overall thickness of 25 cm, being built of 20 cm hollow blocks with a 2.5 cm mortar rendering on each face.

(A) Façade with traditional joinery.

The windows and glazed doors were of traditional design, timber framed and glazed in the usual way with 2.9 mm thick glass. The windows opened inwards in the French manner.

Their dimensions were:

	Total Height of Opening cm	Height of Reveal cm	Total Width cm	Width between Reveals cm
Door	228	225	86	80
Window	138	135	146	140

Except where otherwise stated in the results, this façade had weatherstripping fitted to improve its air-tightness so that the effect of the glazing could be assessed more easily.

(B) Façade with sealed glazing.

The second type of façade was one in which the openings, instead of being closed in the traditional manner, were closed by 10 mm thick sheets of glass sealed directly to the masonry.

The dimensions of the glazed areas were:

Door - 226 x 79 cm

Window - 134 x 138 cm

Sealed glazing of this kind is a rather unusual arrangement. It was used because it provides the maximum degree of air-tightness, thereby giving an insulation value that is due solely to the layer of glass and is unaffected by an imperfectly controlled degree of sealing against the passage of air.

Measurements were first made on these two façades in their bare state. This was followed by measurements on the same façade fitted successively with open balconies (balconies with open-work guard-rails); closed balconies (i.e. with their guard-rail spaces filled in); with loggias; and finally with each of the above arrangements of balconies or loggias but with the addition of acoustic absorbent material affixed to their internal surfaces (figure 5).

5. Sound Insulation Provided by the Façades Alone

The insulation values given by the two types of façade alone are presented for different values of the angle of incidence (θ) of the sound waves reaching the façade:

$$\theta = \text{Arc cos } (\cos \phi \cos \gamma)$$

Measurements were made with the angle θ given the value zero and values within the range $30° \pm 10°$, $60° \pm 10°$ and $80° \pm 5°$.

The values of the normalized sound insulation given by these façades are not exactly the same for a given angle of incidence if the values of the angles ϕ and γ are different. This appears to be attributable to diffraction of the sound waves at the edges of the door and window openings, the effect of such diffraction being slightly different for the same angle of incidence if the values of the angles ϕ and γ are not the same. Otherwise a center of symmetry would have to be assumed for each individual façade.

Examination of the results obtained (figures 6 and 7) shows that there is little difference between the sound insulation obtained with 10 mm glass and that with ordinary glazing using 2.9 mm thick. Indeed, in the range of frequencies from 800 to 1600 Hz, that is the upper medium frequencies, the normal glazing has a better sound insulation than the 10 mm thick glass. This is due to coincidence effects, the critical frequencies for 10 mm glass and ordinary window glass being 1200 and 4000 Hz respectively, i.e. in the medium and high frequency ranges respectively. On the other hand, at low frequencies, and at all frequencies for angles of incidence less than 40°, the thick glass is a distinctly better insulator than the window glass, which is in accordance with the mass law.

It will be seen that the shape of the curve of sound insulation plotted against frequency varies according to the angle of incidence, especially for the façade with sealed glazing, whereas the average insulation changes but little with incidence. Nevertheless the thick glass displays a slight minimum in the insulation curve at an angle of

about 60° and a maximum at an angle of incidence below 30°. Table I has been drawn up to illustrate these facts. In this table values are given of the average sound insulation for the low, medium and high-frequency bands[3/] and the overall insulation calculated in dB(A) for the traffic noise frequency distribution[4/]. These values are given for each value of the incidence, as defined by pairs of values of the angles ϕ and γ.

As for the effect of sealing the doors and windows, it can be seen that the increase in insulation achieved by weatherstripping these openings is slightly greater for high frequencies than for low, and slightly greater for small angles of incidence than for great. It is of the order of 2 to 6 dB, which is not negligible.

6. The Effect of Opening a Traditional Type of Window upon the Sound Insulation that It Provides

Table I includes values (average and overall) of the sound insulation of the traditional façade unit with the door closed and with the window successively:

- closed (with weatherstripping fitted),
- closed (without weatherstripping),
- partly open, the opening light being held by the stay,
- wide open.

As long as the angle of incidence of the sound waves does not exceed 70° or so, this angle has only a very slight influence upon the value of the insulation provided by the traditional façade, whatever position the opening light may be in.

Under these conditions, the traditional façade wall provides an overall sound insulation of:

4 to 6 dB(A) with the window wide open,

12 dB(A) with the window partly open,

22 dB(A) with the window closed but not weatherstripped,

27 db(A) with the window closed and fitted with weatherstripping.

Thus, the sound insulation is very small when the window is open.

When the angle of incidence θ assumes very high values, however, the overall sound insulation values are a little higher, especially for the cases when the window is open.

[3/]Cahier 554; Volume No. 66; C.S.T.B.; February 1964

[4/]Cahier 599; Volume No. 71; C.S.T.B.; December 1964 (See figure 21)

For example, when θ is greater than 80°, the overall insulation is:

8 to 12 dB(A) with the window wide open,

14 to 17 dB(A) with the window partly open,

25 dB(A) with the window closed but not weatherstripped,

29 dB(A) with the window closed and fitted with weatherstripping.

Under these conditions the sound insulation provided by the open window is no longer negligible.

7. Sound Insulation Provided by Façade with Balconies and Loggias (without Absorbent Materials)

The experimental work continued with measurements of the sound insulation obtained when both the façades were fitted with open balconies, closed balconies, and loggias (figure 5). The traditional façade was tested with its window wide open and its door closed, whereas the façade incorporating sealed glazing was tested in the same condition as described in Section 5 above.

The normalized sound insulation was measured for the various values of the angles of elevation (ϕ) and azimuth (γ) already given. The angle of incidence θ has little or no meaning when balconies are fitted.

Figures 8, 9 and 10 each show four graphs representing the normalized sound insulation for angles of elevation $\phi = 0$, $\phi = -30°$, $\phi = -60°$, and $\phi = -80°$ at angles of azimuth 0, 30°, 60° and 80° (except for $\phi = -80°$ when γ takes the value 0 only).

The balcony or the loggia contributes only a slight increase in the insulation and then only if the angle of elevation is great enough:

- at least 60° in the case of open balconies,

- at least 30° in the case of closed balconies and loggias.

The insulation may even be slightly reduced for angles of evelation less than those given above, because the balcony acts as a collector of sound rather than as a protective screen. On the other hand, the insulation is slightly improved for large angles of elevation and azimuth, due to the fact that the balcony shades the glazing and, in addition, reflects the diffracted waves at an incidence less than that of the direct waves. The latter effect may either have practically no effect upon the insulation (in the case of a window of traditional type) or may improve the insulation (in the case of sealed glazing)

Table II gives the increase in overall sound insulation for a frequency distribution corresponding to that of traffic noise when a façade is fitted with a balcony or a loggia.

8. Façades with Balconies and Loggias with Sound-Absorbent Material Applied to the Inner Surfaces

It was noted that the effect of balconies and loggias on the sound insulation of the rooms was slight. This fact can be attributed to the reflection of the sound waves incident upon the underside of the balcony (or the loggia) of the story above, which tends to create an image of the sound source in direct view of the shaded room. Consequently, attempts were made to eliminate this reflection by applying an effective sound absorbent material to the inner surfaces of balconies and the undersides of those on the upper story.

The improvement effected by this absorbent material becomes distinctly greater as the angle of incidence is increased and is greater for the loggia than for the closed balcony and, a fortiori, for the open balcony (see figures 11, 12, 13, and Table III).

For an open balcony this improvement is always very small but it becomes appreciable (approximately 5 dB(A) improvement) in the case of the closed balcony for angles of elevation in excess of 30° (absolute value), and reaches about 10 dB(A) in the case of the loggia, also for angles of elevation greater than 30°.

9. Calculation of Sound Insulation for a Line Source Noise

Knowing the insulation values given by façades when the sound arrives from a definite direction, one can deduce the insulation that would apply when the source is not a point but a continuous straight line, as is the case of noise from a main road at an unobstructed site. All that is required is to integrate the sound intensity emitted from each element of the road and transmitted through the façade with the attenuation corresponding to the angle of incidence.

Table IV gives values of the difference between the free-field sound pressure level at the center of the façade and the reverberant sound pressure level within the room, for the various types of façade investigated and for various values of the angle ϕ subtended by the center-point of the façade at the point on the road nearest to the façade. It can be seen that for angles of elevation ϕ greater than 45° the insulation of the façade, when fitted with an absorbent-lined loggia and with the window wide open, is considerable, exceeding 15dB(A).

10. Conclusions

Surveys[5] have shown that, for external noise from a main traffic route, the average sound pressure level would be considered to be acceptable if it did not exceed 63 dB(A) immediately outside the façade, which corresponds to 60 dB(A) measured under free-field conditions (for example, before the building is erected).

From the measurements reported above, it can be deduced that this corresponds to sound pressure levels within the rooms of about 40 dB(A) with the window closed and 55 dB(A) with the window open. This could be regarded as an assessment of the requirements of the occupants.

The presence of a loggia lined with absorbent material and of sufficient elevation ($\phi > 45°$) with respect to the road in front of a façade enables the free-field external noise level to rise to 70 dB(A) before the above internal noise level criteria are exceeded.

If such favourable circumstances cannot be arranged, then, when the external noise level exeeds 60 dB(A), the rooms must be fitted with mechanical ventilation and air-conditioning so that the windows can be kept closed when the rooms are occupied.

In this case, the external free-field sound pressure level is measured and the type of façade is selected on the basis of the data given in the accompanying tables, so that the insulation the façade provides will be sufficient to keep the internal sound level down to 40 dB(A).

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[5] Cahier 762; Volume No. 88; C.S.T.B.; October 1967

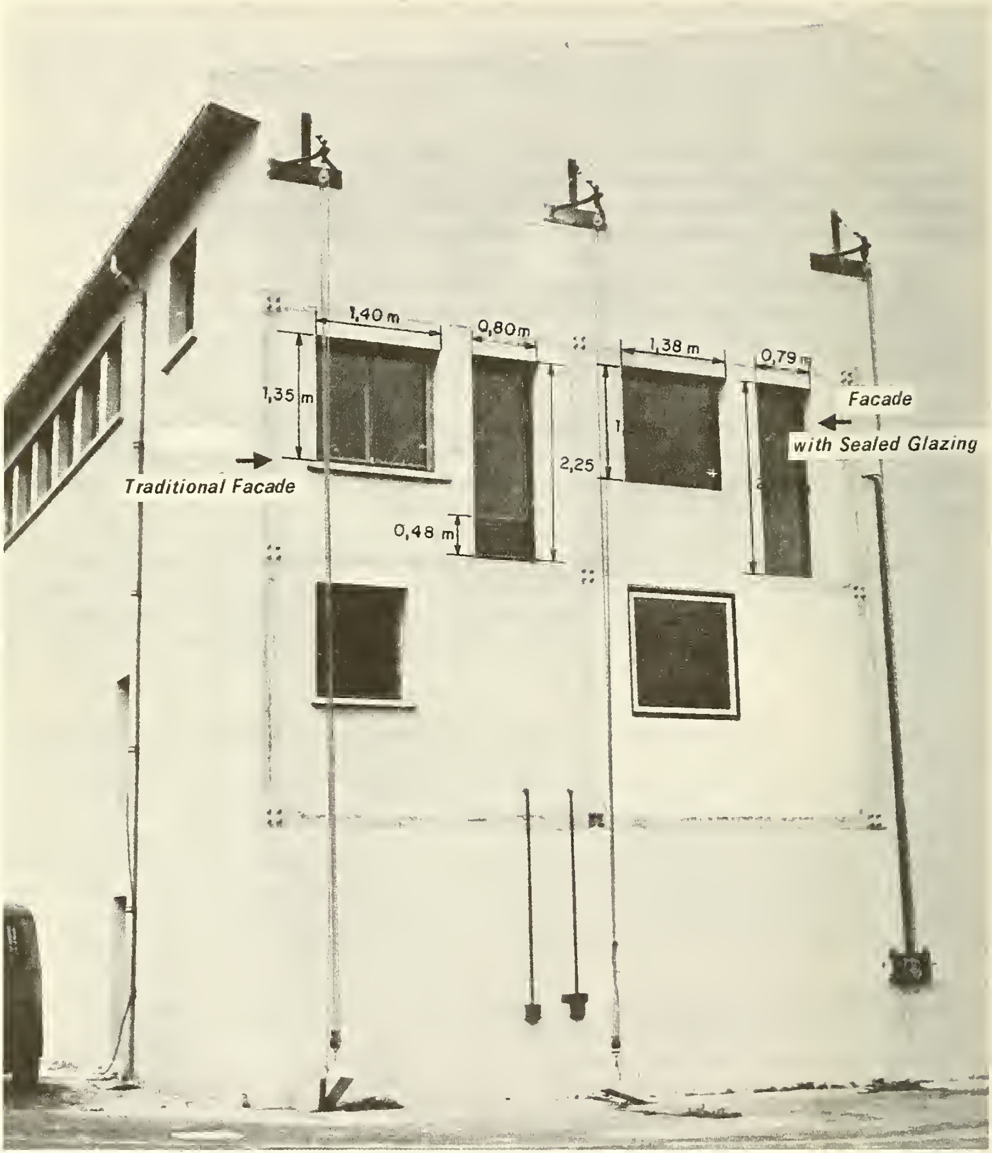


Figure 1
Experimental Building for investigating the sound insulation of facade walls.

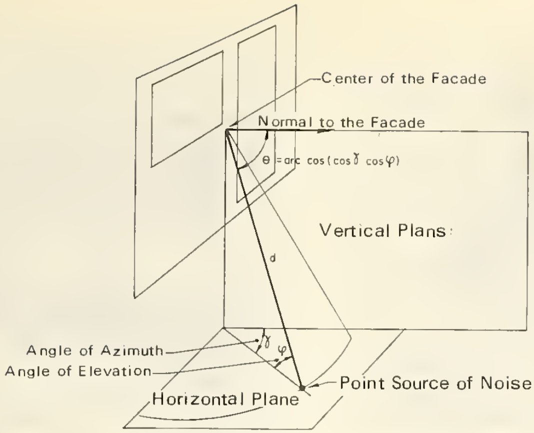


Figure 2. Geometrical definitions

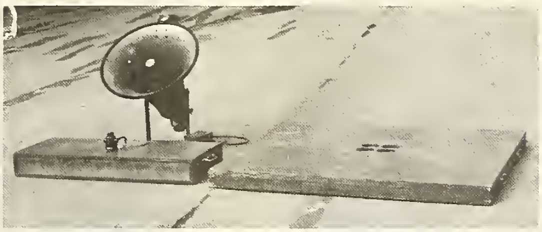


Figure 3. Sound sources used for the measurement of the sound insulation of facades.

Table showing the sound sources used in the measurements for the various frequency bands and elevations.

Elevation \ Frequency	100 to 500	500 to 3150
-80° and -60°	4 LS Baffle	Exponential horn LS
-30° and 0°	9 LS Column	Exponential horn LS

Figure 4.

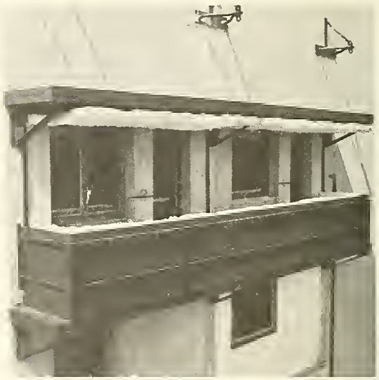
Microphone traversed using a turntable within the testroom (fitted with traditional–type facade wall.)

Figure 5 Facades

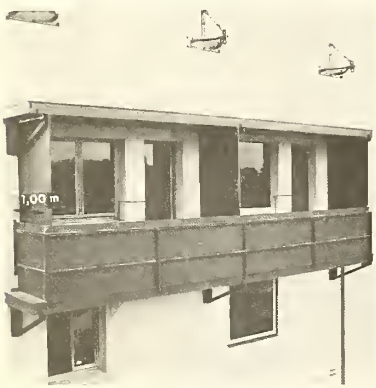
with open balcony (see–through)

with open balcony and absorbent lining

with closed balcony (solid)



with closed balcony and absorbent lining



with loggia

with loggia and absorbent lining

Table 1 Bare Facades

Average insulation values, in dB, for low (G), medium (M) and high (A) frequencies, and overall insulation (D), in dB(A), calculated for a traffic—noise frequency distribution (cahier 559, Figure 21, d 3 m).

Incidence															
		Azimuth γ	0	30	60	75	0	30	60	75	0	30	60	80	0
		elevation φ	0	0	0	0	– 30	– 30	– 30	– 30	– 60	– 60	– 60	– 60	– 80
		angle θ	0	30	60	75	30	40	64	80	60	64	75	85	80
Facade with 10 mm thick sealed glazing		G	30	30	33	32	30	29	30	30	30	29	30	31	30
		M	34	32	31	32	32	31	30	32	29	27	29	29	28
		A	42	36	40	42	37	34	37	41	37	37	43	46	44
		D	**32,5**	**32**	**31**	**32**	**32,5**	**31**	**30**	**32**	**29**	**28**	**30**	**30**	**29**
Traditional Facadas with ordinary glazing (2.9 mm):	Window and door weatherstripped	G	22	23	22	26	23	24	24	26	23	22	25	26	23
		M	30	29	29	30	26	26	27	31	29	29	28	32	30
		A	34	33	30	33	31	29	30	33	30	30	32	35	35
		D	**28**	**28**	**27**	**30**	**26**	**26**	**27**	**29**	**27**	**27**	**27**	**29**	**28**
	Window and door closed	G	19	20	20	23	20	21	21	23	21	22	23	25	20
		M	24	24	26	27	24	23	24	27	27	24	26	28	26
		A	23	23	21	23	22	21	20	24	27	25	27	29	28
		D	**22**	**22**	**22**	**26**	**22**	**22**	**21**	**25**	**25**	**24**	**25**	**27**	**25**
	Window partly open (door closed)	G	11	12	11	15	12	14	15	17	13	11	14	16	11
		M	14	14	13	17	12	11	14	18	14	13	14	17	16
		A	14	15	13	13	13	11	12	17	15	13	16	18	18
		D	**12**	**13**	**12**	**15**	**12**	**11**	**13**	**17**	**13**	**12**	**14**	**17**	**14**
	Window open (door closed)	G	8	9	8	11	9	10	10	12	10	8	10	13	8
		M	4	5	7	8	4	3	9	12	8	6	9	11	11
		A	3	4	6	7	4	4	8	12	7	7	10	12	13
		D	**4**	**4**	**6**	**8**	**4**	**4**	**8**	**12**	**7**	**7**	**9**	**11**	**10**

Figure 6. Normalized sound insulation for 'bare facades'.

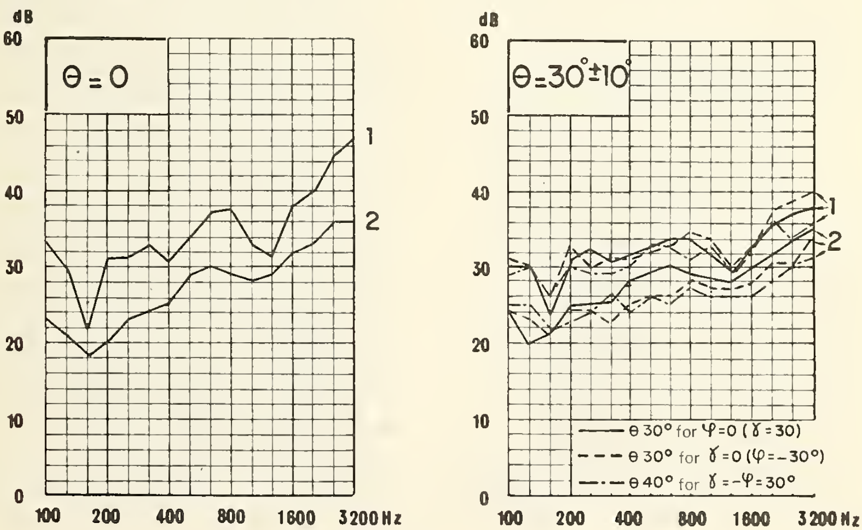


Figure 6. (cont'd.)

1. Sealed glazing (10 mm thick).

   Volume of test—room: 34 m^3

2. Traditional window, weather-stripped (normal glazing).

   Area of windows: 3.6 m^2

NOTE: For clarity, the results from angles of incidence which give insulation values that differ from one another by very little are grouped together (expressed as the average for 2 or 3 angles of incidence.)

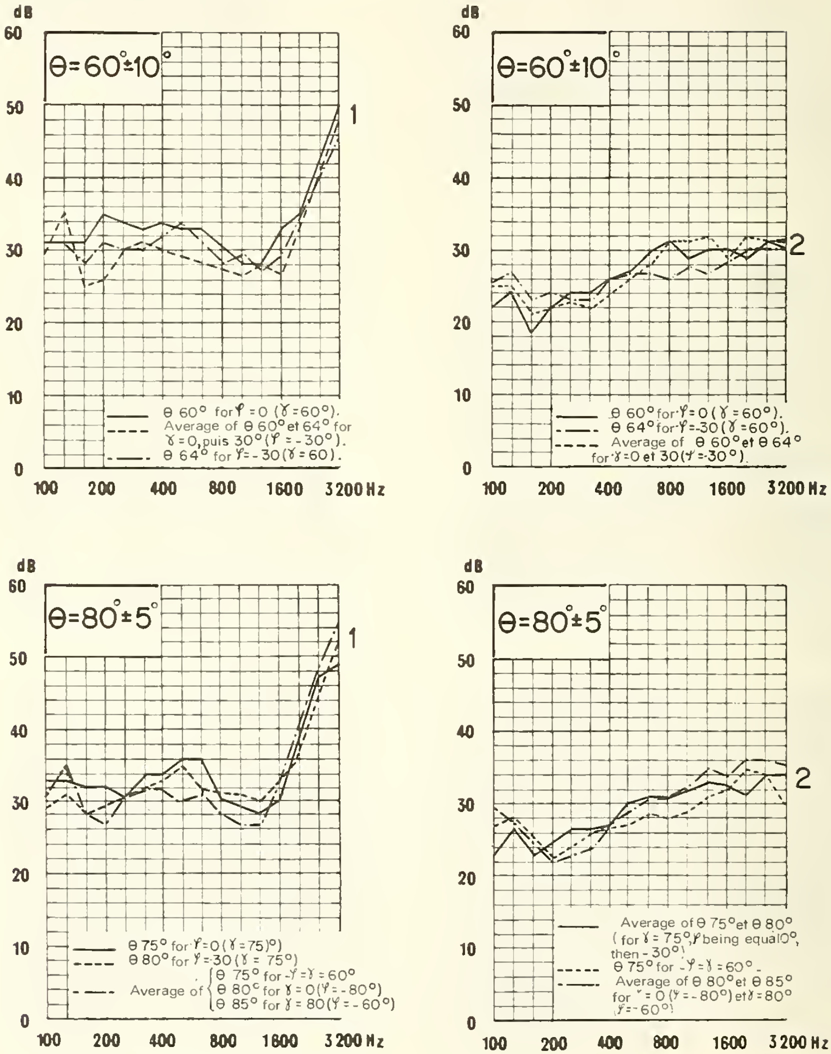


Figure 7.

Increase in normalized sound insulation when normal glazing is replaced by 10 mm thick glazing (bard facade).

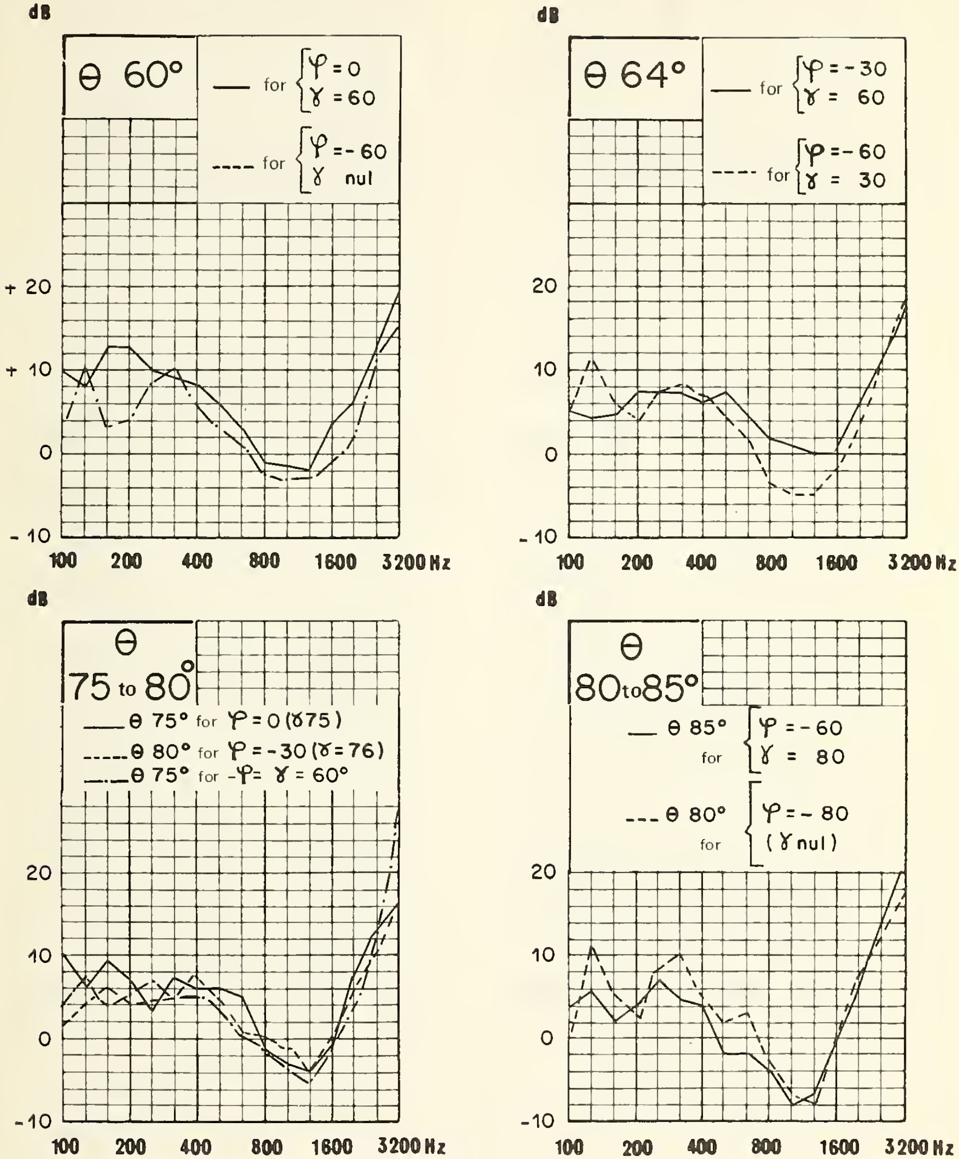
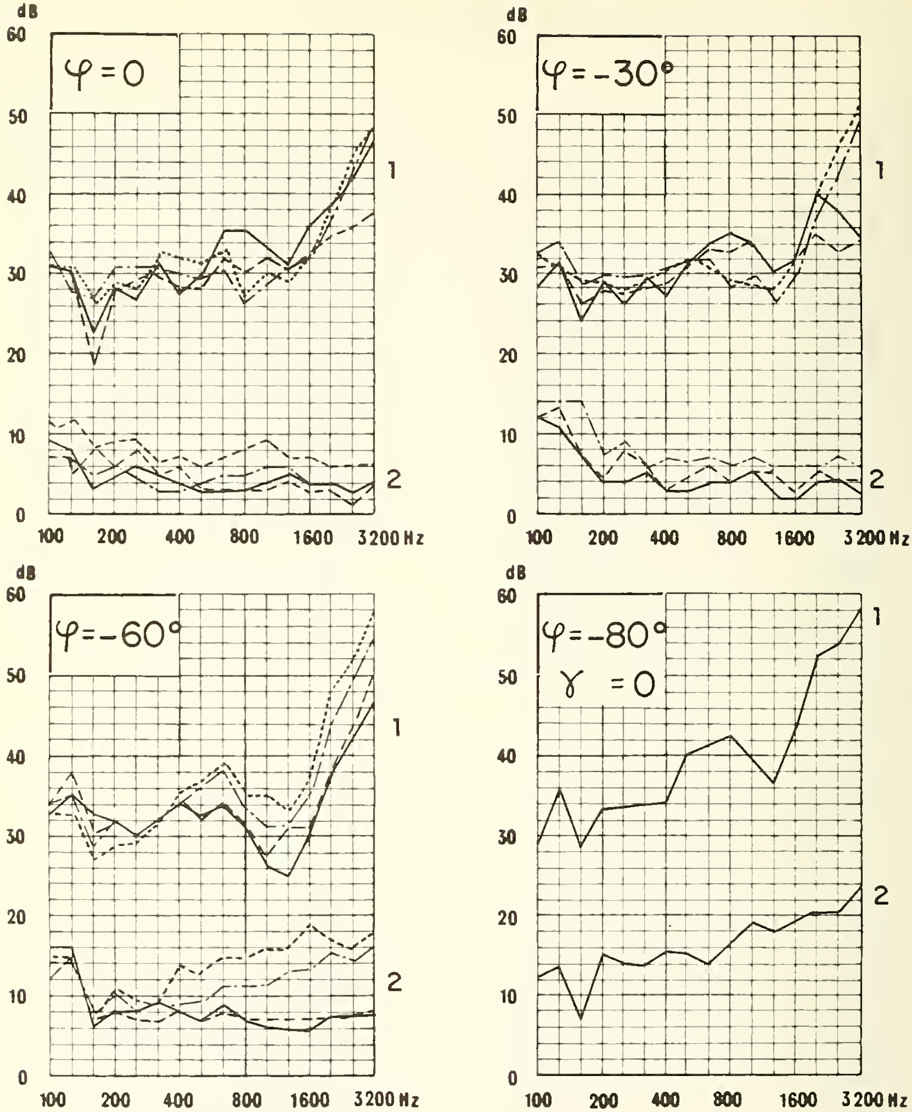


Figure 8 *Open Balcony*



1. 10 mm thick sealed glazing (3.6 m^2)

2. Traditional window, open (1.8 m^2)

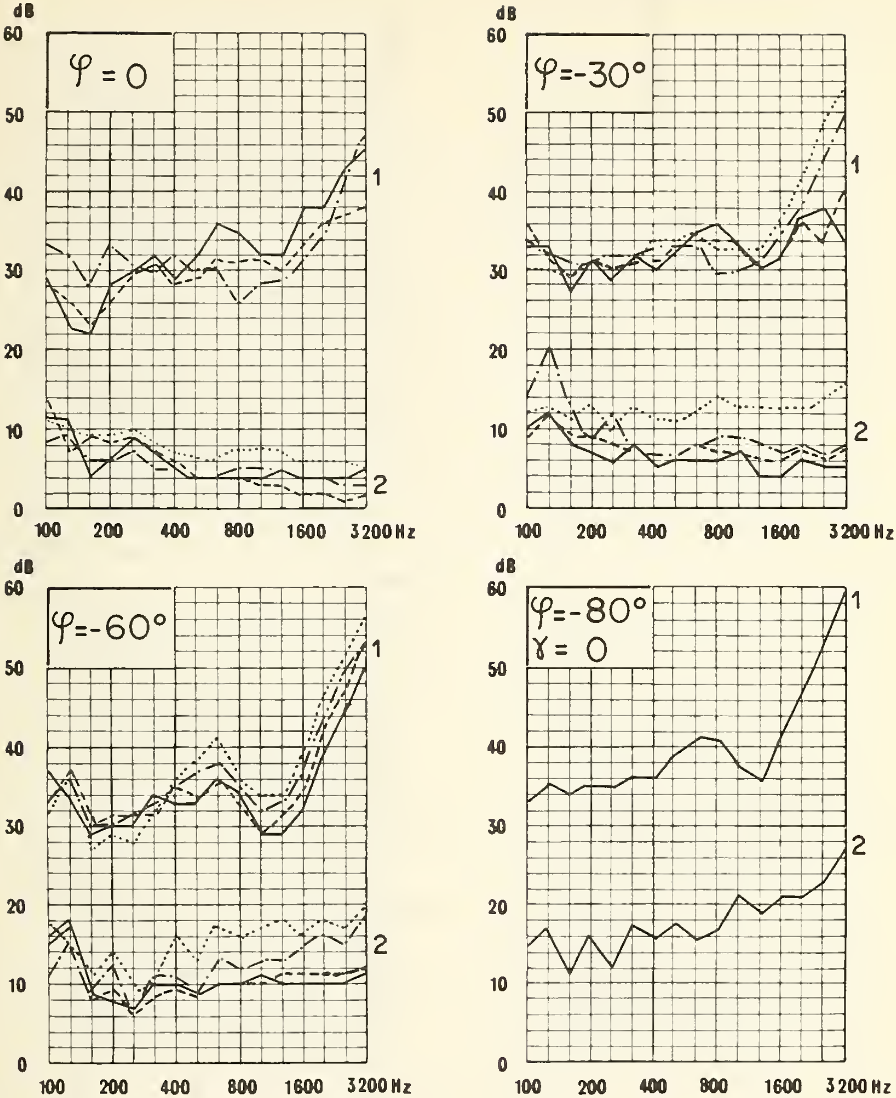
Volume of test–room: 34 m^3

Angles of Azimuth

——— γ = 0   – – – γ = 30°

—·— γ = 60°   .... γ = 80°

Figure 9. *Closed Balcony*



1. 10 mm thick sealed glazing (3.6 m^2)

2. Traditional window, open (1.8 m^2)

Volume of test–room: 34 m^3

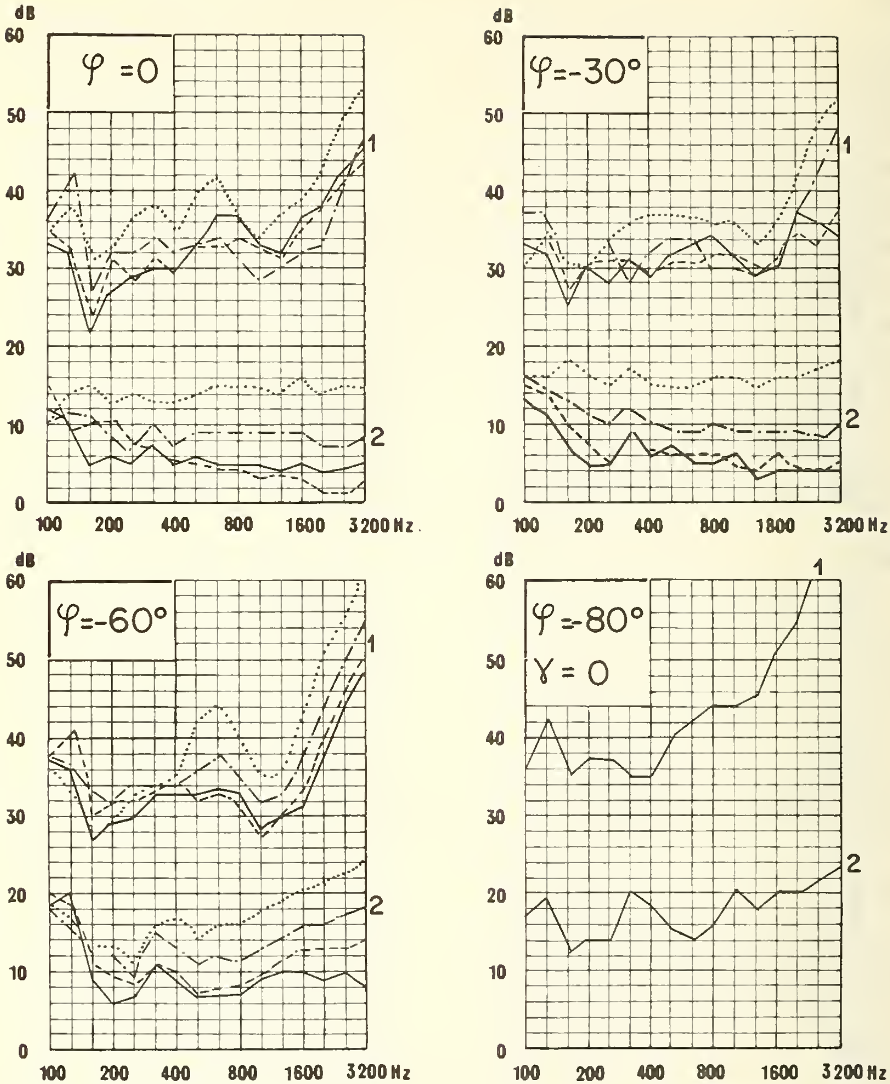
Angles of Azimuth

——— γ = 0 — — — γ = 30°

—·— γ = 60° .... γ = 80°

Figure 10.

Normalized Sound insulation: Loggia



1. 10 mm thick sealed glazing (3.6 m^2)

2. Traditional window, open (1.8 m^2)

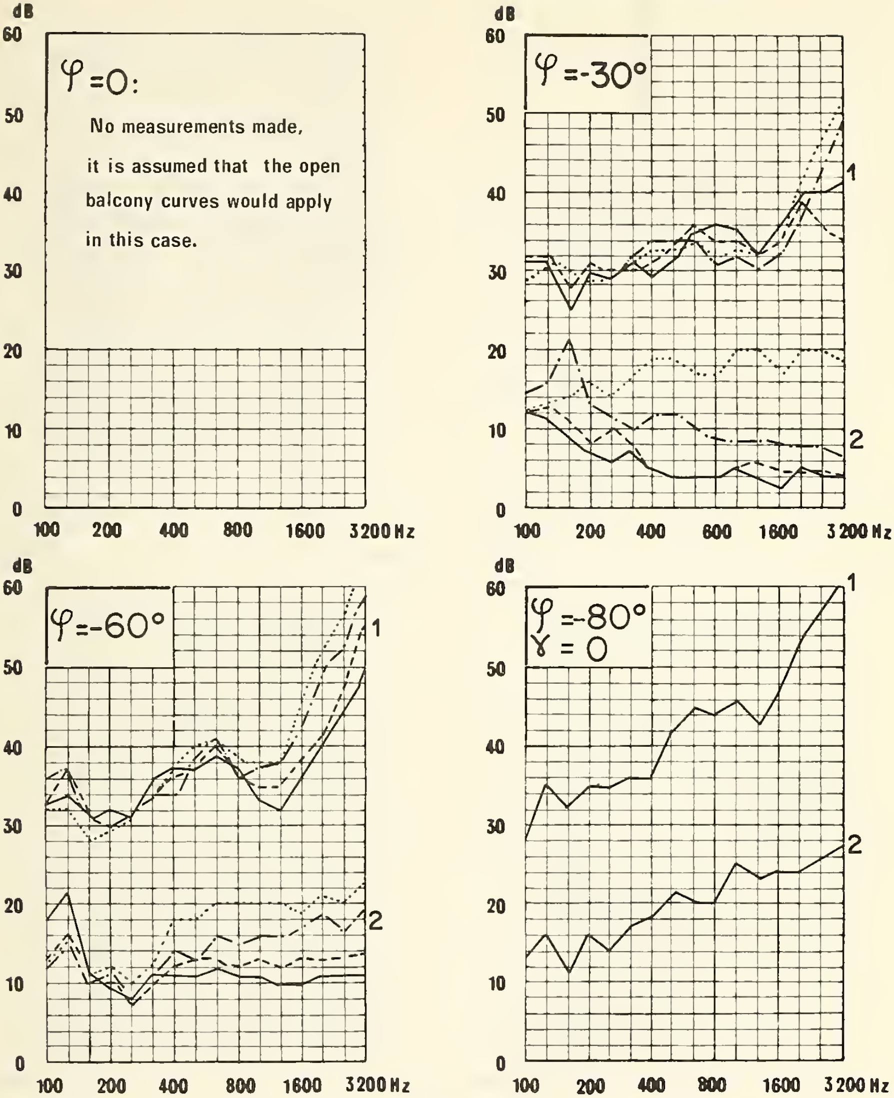
Volume of test–room: 34 m^3

Angles of Azimuth

——— γ = 0   — — — γ = 30°

—·— γ = 60°   .... γ = 80°

Figure 11. Normalized sound insulation: open balcony with absorbent lining



1. 10 mm thick sealed glazing (3.6 m^2)
2. Traditional window, open (1.8 m^2)

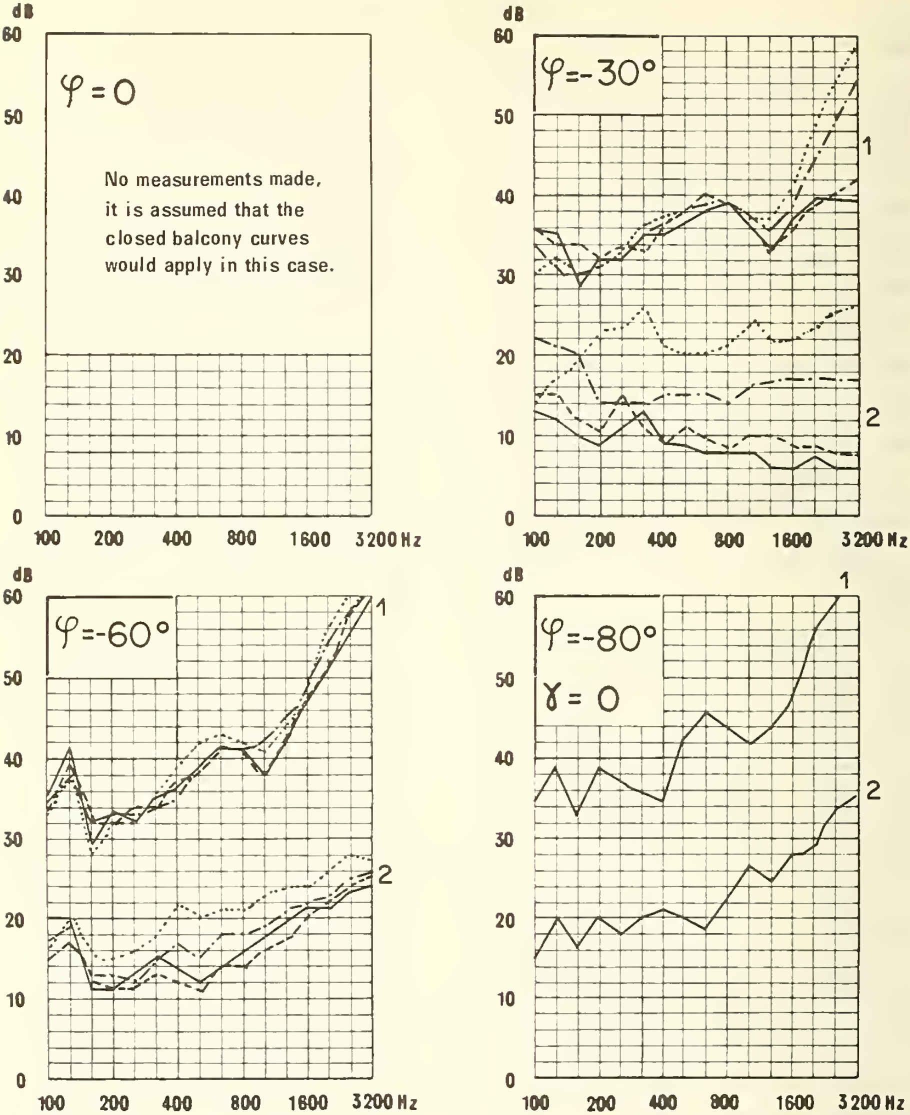
Volume of test-room: 34 m^3

Angles of Azimuth

——— γ = 0   – – – γ = 30°

—·— γ = 60°   .... γ = 80°

Figure 12. *Normalized sound insulation: closed balcony with absorbent lining*



1. 10 mm thick sealed glazing (3.6 m^2)

2. Traditional window, open (1.8 m^2)

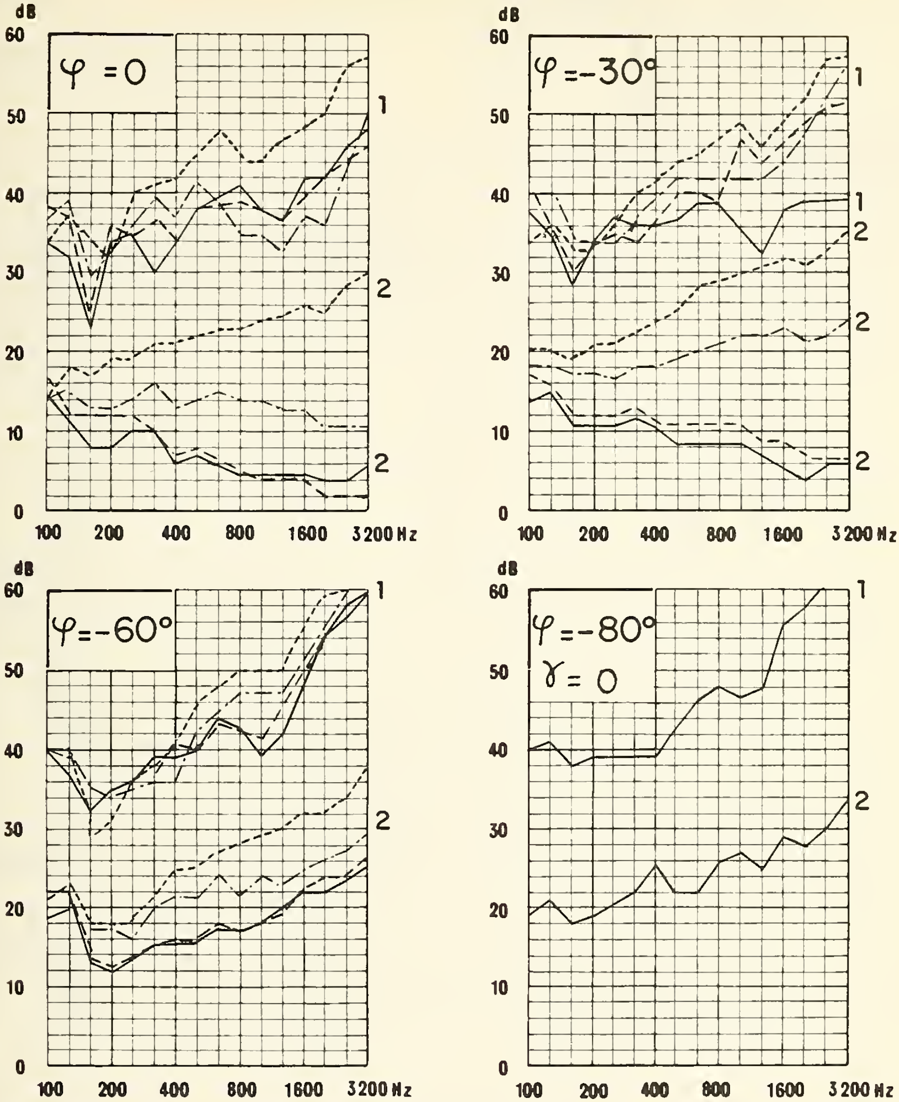
Volume of test–room: 34 m^3 m³.

Angles of Azimuth

—— γ = 0   – – – γ = 30°

—·— γ = 60°   .... γ = 80°

Figure 13. Normalized Sound insulation: Loggia with absorbent lining.



1. 10 mm thick sealed glazing (3.6 m^2)

2. Traditional window, open (1.8 m^2)

Volume of test–room: 34 m^3

Angles of Azimuth

——— γ = 0   — — — γ = 30°

—·— γ = 60°   .... γ = 80°

Table II

Increase in the sound insulation of a room from external noise when the facade is fitted with a balcony or loggia having sound absorbent material applied to its internal surfaces.

The values given below represent the average increases in insulation for low (G), medium (M) and high (A) frequency bands and the increases in overall insulation, in dB(A), (indicate by the letter D) for the frequency distribution corresponding to traffic noise.

Incidence	Azimuth γ		0°	30°	60°	75°	0°	30°	60°	75°	0°	30°	60°	80°	0°
	Elevation φ		0°	0°	0°	0°	– 30°	– 30°	– 30°	– 30°	– 60°	– 60°	– 60°	– 60°	– 80°
Open Balcony:	Traditional	G	– 3	– 2	– 2	– 3	– 3	– 2	– 1	– 2	– 1	0	– 1	– 2	+ 4
	Window	M	0	– 1	– 1	– 1	+ 0	+ 2	– 1	+ 1	0	+ 1	+ 2	+ 3	+ 5
	Open	A	+ 1	– 1	– 1	– 1	– 1	0	– 1	+ 2	0	0	+ 4	+ 5	+ 7
		D	0	– 1	– 1	– 1	– 1	+ 1	– 1	+ 1	0	+ 0,5	+ 2	+ 3	+ 5
	Facade	G	– 2	– 2	– 3	– 2	– 2	0	+ 1	0	+ 3	+ 3	+ 2	– 1	+ 2
	with	M	– 1,5	– 2	– 2	– 1	0	+ 1	0	– 2	+ 1	+ 5	+ 5	+ 7	+ 11
	sealed	A	– 1,5	– 1	0	– 1	– 1	– 1	+ 3	+ 2	+ 2	+ 4	+ 3	+ 3	+ 7
	glazing	D	– 1,5	– 1,5	– 1,5	– 1	– 1	0	+ 1	– 1	+ 2	+ 4	+ 4	+ 5	+ 9
Closed Balcony:	Traditional	G	– 1	– 1	– 2	– 2	– 1	– 1	0	– 1	0	+ 2	0	+ 1	+ 6
	Window	M	0	– 1	– 2	– 2	+ 2	+ 3	0	0	+ 2	+ 3	+ 3	+ 4	+ 7
	open	A	+ 1	– 2	– 2	0	+ 1	+ 2	– 1	+ 1	+ 3	+ 4	+ 5	+ 6	+ 9
		D	0	– 1	– 2	– 2	+ 2	+ 2	0	0	+ 3	+ 3	+ 3	+ 4	+ 7
	Facade	G	– 3	– 3	– 2	– 2	+ 1	+ 1	+ 2	0	+ 2	+ 3	+ 2	0	+ 5
	with	M	– 1	– 2	– 2	– 1	+ 1	+ 1	+ 1	+ 1	+ 3	+ 6	+ 6	+ 7	+ 10
	sealed	A	– 1	0	+ 1	– 1	– 2	+ 2	+ 5	+ 4	+ 5	+ 7	+ 3	+ 2	+ 7
	glazing	D	– 1	– 1,5	– 1,5	– 1	0	+ 1	+ 2	+ 1	+ 3,5	+ 6	+ 5	+ 5,5	+ 9
Loggia:	Traditional	G	– 1	+ 1	+ 2	+ 2	– 1	0	+ 2	+ 4	+ 2	+ 5	+ 4	+ 2	+ 8
	Window	M	+ 1	– 1	+ 1	+ 6	+ 1	+ 3	0	+ 3	0	+ 3	+ 3	+ 6	+ 6
	open	A	+ 1	– 1	+ 2	+ 8	0	+ 1	+ 1	+ 5	+ 2	+ 6	+ 7	+ 11	+ 8
		D	+ 0,5	0	+ 1,5	+ 6	+ 0.5	+ 2	+ 1	+ 3,5	+ 1,5	+ 4	+ 4	+ 6	+ 7
	Facade	G	– 1	0	0	+ 3	0	+ 2	+ 3	+ 3	+ 2	+ 5	+ 5	+ 1	+ 7
	with	M	0	0	0	+ 5	– 1	0	+ 2	+ 4	+ 3	+ 5	+ 6	+ 10	+ 14
	sealed	A	+ 1	+ 4	– 2	+ 4	– 3	0	+ 2	+ 4	+ 4	+ 6	+ 4	+ 7	+ 15
	glazing	D	+ 0,5	0	– 0,5	+ 5	– 1,5	0	+ 2	+ 3,5	+ 3	+ 5	+ 6	+ 8	+ 12

Table III

Increase in the sound insulation of a room from external noise due to the presence of a balcony or a loggia (without sound–absorbent linings).

The values given below represent the average increase in insulation for low (G), medium (M) and high (A) frequency bands and the increases in overall insulation, in dB(A) (indicated by the letter D) for the frequency distribution corresponding to traffic noise.

Incidence		Azimuth γ	0°	30°	60°	75°	0°	30°	60°	75°	0°	30°	60°	80°	0°
		Elevation φ	0	0	0	0	— 30′	— 30°	— 30°	— 30°	— 60^3	— 60^3	— 60′	— 60^3	— 80°
Open Balcony with sound–absorbent lining:	Traditional window open	G	0	0	0	0	— 1	0	+ 3	+ 2	+ 2	+ 2	+ 1	0	+ 6
		M	0	0	0	0	0	+ 2	+ 1	+ 6	+ 2	+ 6	+ 6	+ 8	+ 9
		A	0	0	0	0	0	+ 1	0	+ 7	+ 3	+ 6	+ 7	+ 8	+ 12
		D	**0**	**0**	**0**	**0**	**0**	**+ 1**	**+ 1**	**+ 5**	**+ 2**	**+ 5**	**+ 6**	**+ 7**	**+ 10**
	Facade with sealed glazing	G	0	0	0	0	— 1	+ 1	+ 1	0	+ 3	+ 4	+ 3	0	+ 3
		M	0	0	0	0	+ 1	+ 2	+ 2	+ 1	+ 7	+ 10	+ 8	+ 10	+ 15
		A	0	0	0	0	+ 2	+ 2	+ 3	+ 3	+ 6	+ 8	+ 8	+ 8	+ 11
		D	**0**	**0**	**0**	**0**	**+ 1**	**+ 2**	**+ 2**	**+ 1**	**+ 6**	**+ 9**	**+ 8**	**+ 7**	**+ 11**
Closed balcony with sound–absorbent lining:	Traditional window open	G	0	0	0	0	+ 2	+ 2	+ 6	+ 8	+ 3	+ 5	+ 4	+ 3	+ 10
		M	0	0	0	0	+ 4	+ 6	+ 6	+ 9	+ 7	+ 8	+ 9	+ 11	+ 11
		A	0	0	0	0	+ 2	+ 5	+ 9	+ 12	+ 15	+ 15	+ 13	+ 14	+ 16
		D	**0**	**0**	**0**	**0**	**+ 3**	**+ 5**	**+ 6**	**+ 9**	**+ 7**	**+ 7**	**+ 8**	**+ 9**	**+ 11**
	Fecede with seeled glazing	G	0	0	0	0	+ 3	+ 5	+ 2	+ 2	+ 4	+ 5	+ 4	+ 2	+ 6
		M	0	0	0	0	+ 4	+ 6	+ 7	+ 6	+ 11	+ 13	+ 11	+ 12	+ 14
		A	0	0	0	0	+ 1	+ 5	+ 10	+ 9	+ 16	+ 17	+ 13	+ 12	+ 13
		D	**0**	**0**	**0**	**0**	**+ 3**	**+ 5**	**+ 6**	**+ 5**	**+ 10**	**+ 11**	**+ 9**	**+ 9**	**+ 12**
Loggia with sound–absorbent lining	Traditional window open	G	+ 3	+ 3	+ 6	+ 7	+ 3	+ 4	+ 7	+ 8	+ 6	+ 8	+ 8	+ 7	+ 12
		M	+ 2	+ 1	+ 7	+ 15	+ 5	+ 8	+ 11	+ 16	+ 9	+ 11	+ 13	+ 16	+ 14
		A	+ 2	— 2	+ 6	+ 20	+ 2	+ 3	+ 15	+ 21	+ 16	+ 17	+ 17	+ 22	+ 17
		D	**+ 2**	**+ 1**	**+ 7**	**+ 12**	**+ 4**	**+ 5**	**+ 11**	**+ 14**	**+ 9**	**+ 11**	**+ 13**	**+ 15**	**+ 14**
	Fecede with seeled glazing	G	+ 1	+ 5	+ 2	+ 5	+ 5	+ 6	+ 7	+ 5	+ 6	+ 8	+ 6	+ 5	+ 10
		M	+ 4	+ 5	+ 6	+ 13	+ 5	+ 10	+ 12	+ 13	+ 12	+ 15	+ 15	+ 18	+ 17
		A	+ 3	+ 7	+ 2	+ 11	+ 2	+ 16	+ 13	+ 13	+ 17	+ 17	+ 13	+ 14	+ 16
		D	**+ 4**	**+ 5**	**+ 5**	**+ 12**	**+ 5**	**+ 10**	**+ 12**	**+ 12**	**+ 12**	**+ 14**	**+ 13**	**+ 14**	**+ 15**

Table IV Sound insulation Δ, in dB (A), defined as the difference between the sound pressure level that would apply at the centre of the façade under free-field conditions and the reverberant sound pressure level within the room immediately behind the façade (volume 34 m^3, reverberation time 0.5 second), when the noise source is a main road, unobstructed and parallel to the façade. (ψ is the angle of elevation of the centre-point of the façade measured from the point on the road nearest to the façade.)

Arrangement of Facade			Value of ψ				
Openings	Balcony or loggia	Absorbent lining (Abs)	15°	30°	45°	60°	75°
Open Window (1.8 m^2)	None		6	6	7	8	10
	Open balcony	Abs	5 5	5 6	7 8	8 11	12 16
	Closed balcony	Abs	5 5	6 8	8 12	9 13	12 19
	Loggia	Abs	7 8	8 11	9 15	11 20	5 23
10 mm sealed glass (3.6 m^2)	None		31	31	31	30	30
	Open balcony	Abs	30 31	31 32	31 33	32 33	33 34
	Closed balcony	Abs	30 32	32 34	32 35	33 36	34 36
	Loggia	Abs	33 38	32 40	32 41	34 42	36 43

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This paper is translated from the French original and is published under the Building Research Division/Centre Scientifique et Technique du Batiment information exchange program.

An investigation was conducted to determine to what extent the installation of balconies and loggias at various angles of elevation from a noise source could improve the sound insulation of a facade wall. Measurements of the sound pressure level were first carried out on two types of facade, one incorporating traditional window joinery and the other incorporating sealed glazing. Following this, the sound insulation provided by facades fitted with open and closed balconies and loggias (with and without sound absorbent materials applied) was determined and compared with the previous measurements. It was found that for angles of elevation greater than 30°, both the closed balcony and the loggia fitted with absorbent materials appreciably improve the sound insulation, whereas the open balcony does not.

17. KEY WORDS (Alphabetical order, separated by semicolons) Facade; noise; sound insulation; sound pressure level; walls.

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